High contrast imaging performance of E-ELT/METIS

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I. ELT-METIS : Science cases and Design

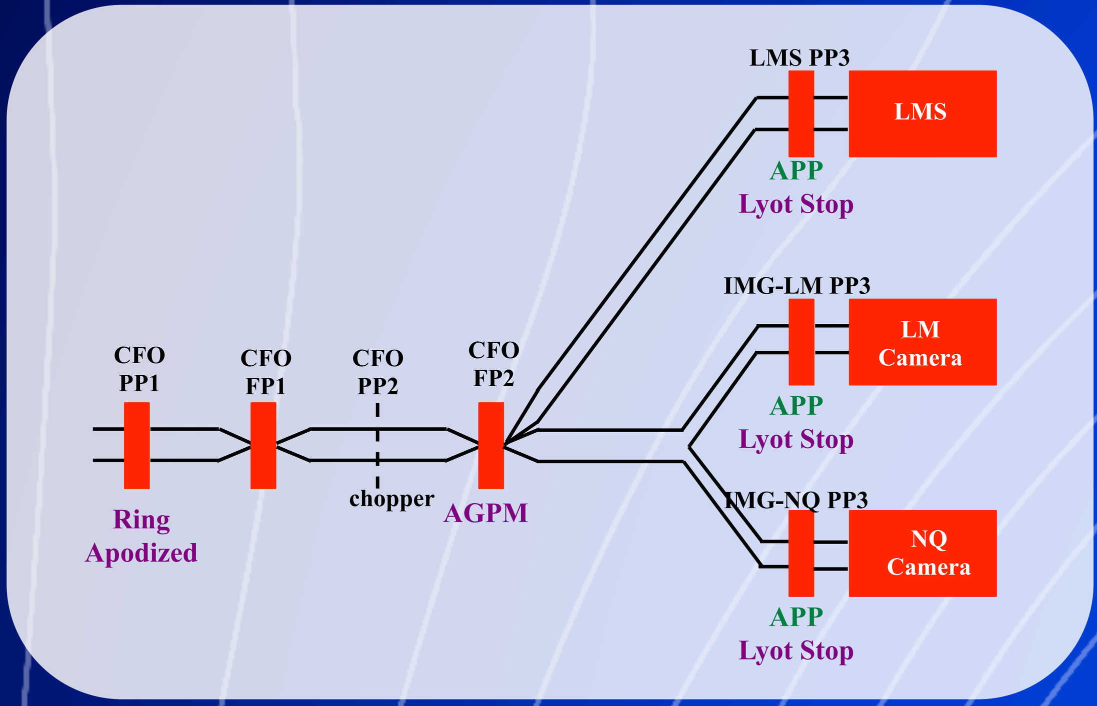


Fig. 1 Metis Fore Optics.

The mid-infrared imager and spectrograph METIS[1] is one of the first-light instrument of ELT. The main science cases include exoplanet detection and characterization down to Earth-sized planets, and the formation and evolution of circumstellar disks, for a better understanding of planetary diversity.

The High Contrast Imaging design includes two of the latest evolutions of stellar coronagraphs, namely the Apodized Phase Plate[2] (APP) and the vortex coronagraph[3]. Custom solutions have been developed to compensate for the non-circular, centrally obscured segmented pupil, in particular the Ring Apodized Vortex Coronagraph[4] (RAVC).

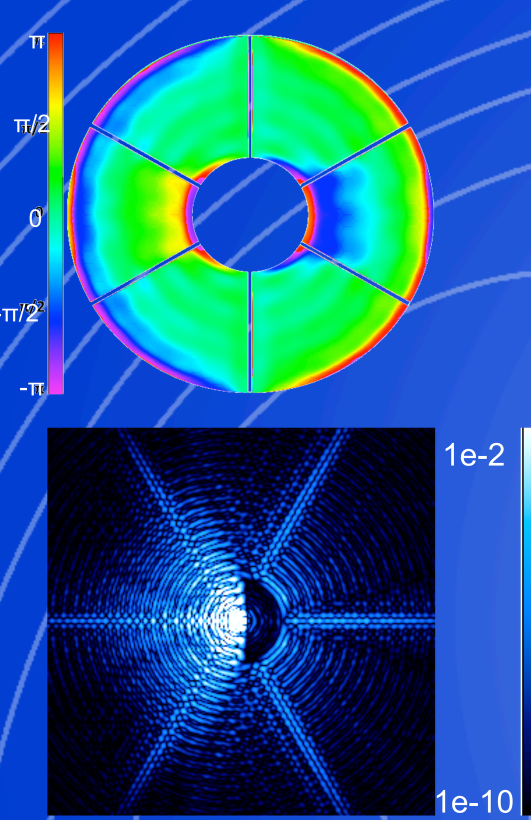


Fig. 2 APP phase and final PSF.

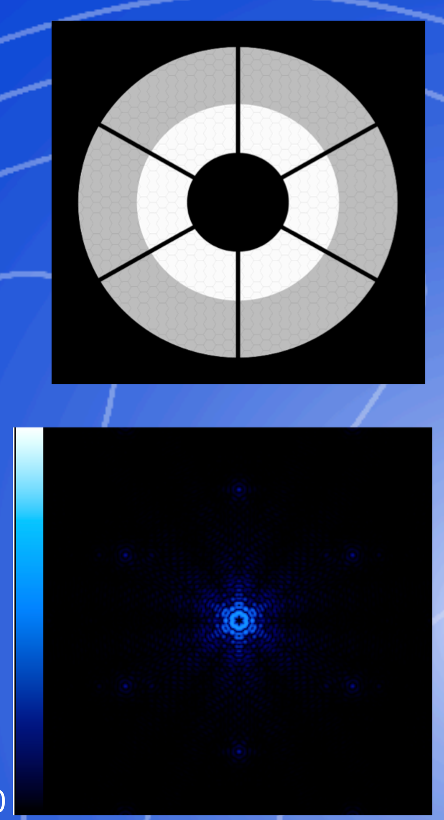


Fig. 3 RAVC pupil and final PSF.

II. Adaptive Optics Residuals: Pyramid or Shack Hartmann

Adaptive Optics Residuals

Natural guide star single conjugated adaptive optics simulations[5] under YAO have been used to estimate the effect of residual wavefront errors. Three main wavefront sensors have been analysed: one Pyramid with 74 sub-apertures (PYR74), one Shack-Hartmann with 60 sub-apertures (SHS60), and one Shack-Hartmann with 74 sub-apertures (SHS74). The three AO simulations have been performed for excellent conditions (0.44" seeing, bright star), for a 2-sec observing sequence.

ADI contrast

Contrast curves have been obtained with the *VIP*[6] package, assuming a bright star (5 mag) with a parallactic angle rotation of 40°. For the WFS comparison, the 2 sec sequence have been analysed as a 1 hour-sequence, where each screen represents 1.63 sec of observation.

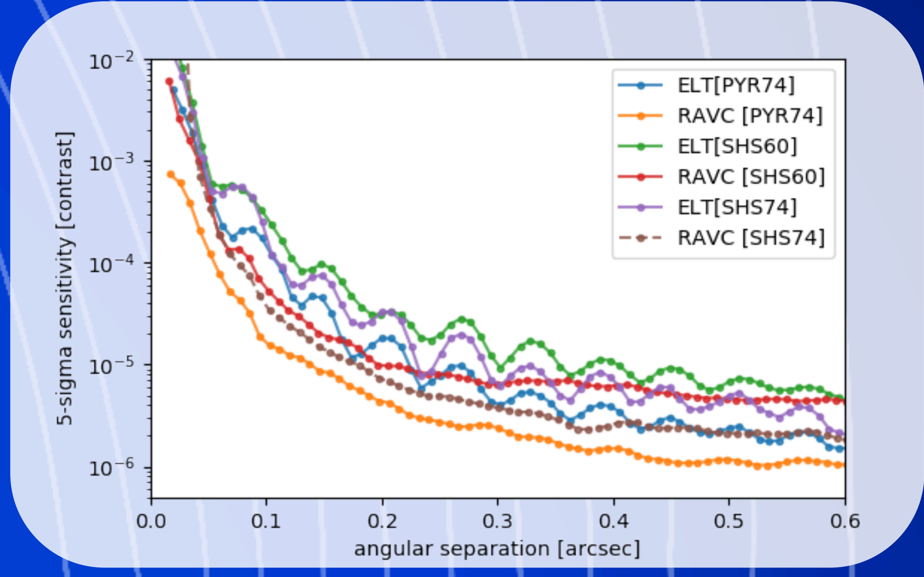


Fig. 4. Contrast curve for the WFS comparison: as expected, the SHS60 has the worst behavior, while the PYR74 has the best performance.

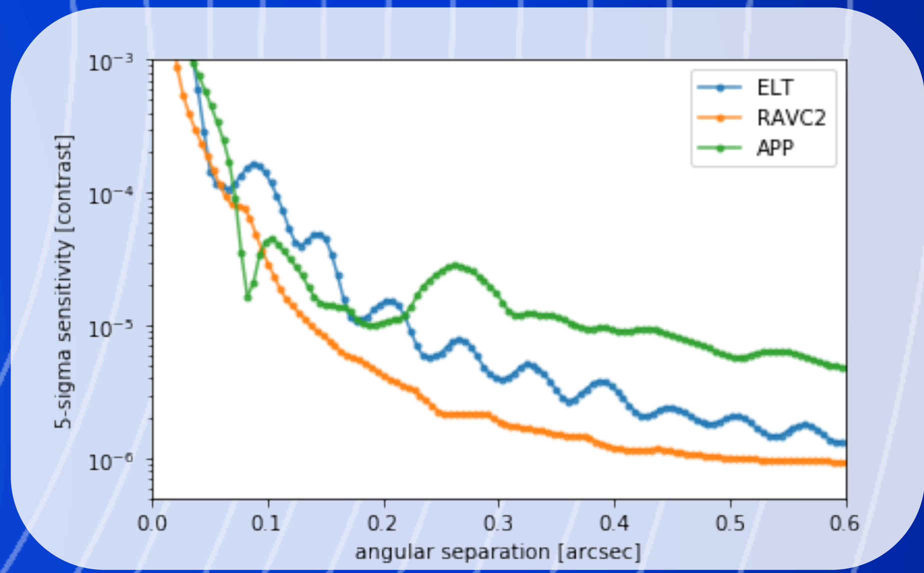


Fig. 5.Preliminary contrast performance for the two coronagraphs: the peculiar behavior of the APP (the dark zone) and the more homogeneous one for the RAVC.

III. Influence of Pointing and Pupil Alignment Errors

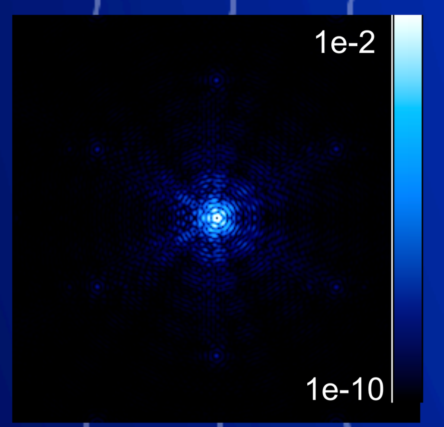


Fig. 7 RAVC PSF with 1mas pointing jitter.

Pointing error

The vortex coronagraph is very sensitive to pointing jitter. We present here two simulations: a quasi-static pointing errors simulation and an high frequency jitter one.

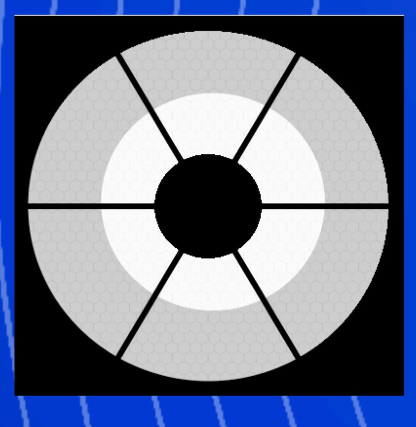


Fig. 8 RAVC pupil with a 3% misalignment in the Ring Apodized.

Pupil alignment error

An internal pupil steering mirror inside METIS will align the ELT exit pupil with the Lyot stop to within 1%. However, because the ring apodizer is located upstream of this mirror, its footprint will move by up to 5% due to the ELT pupil instability.Here we present two simulations: a dynamic and a quasi-static alignment errors simulations.

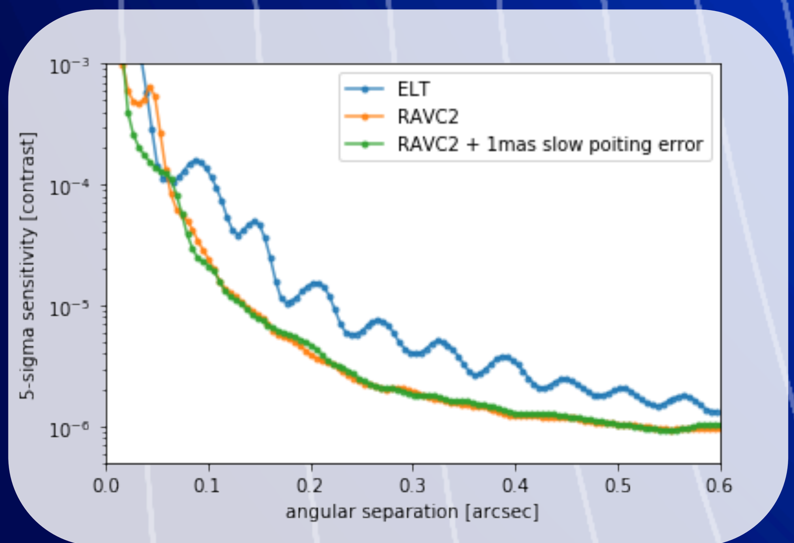


Fig. 9. Contrast performance for the quasi-static pointing errors.

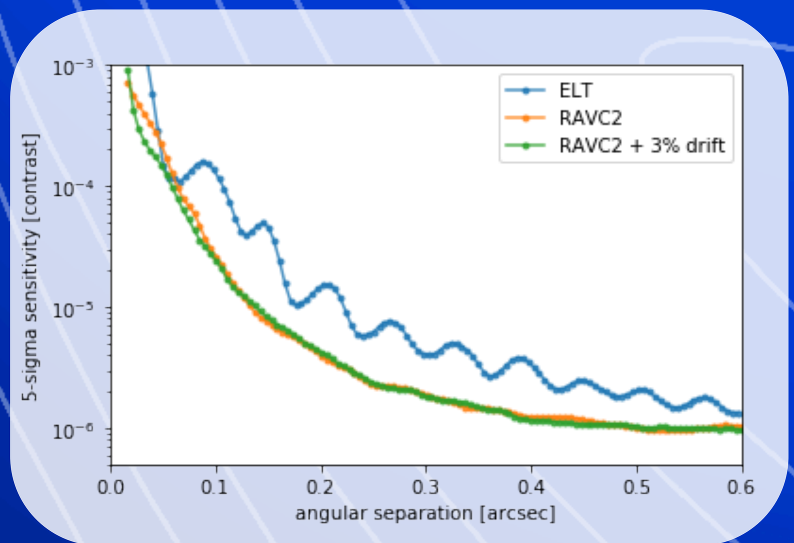


Fig. 10. Contrast performance for the quasi-static alignment errors.

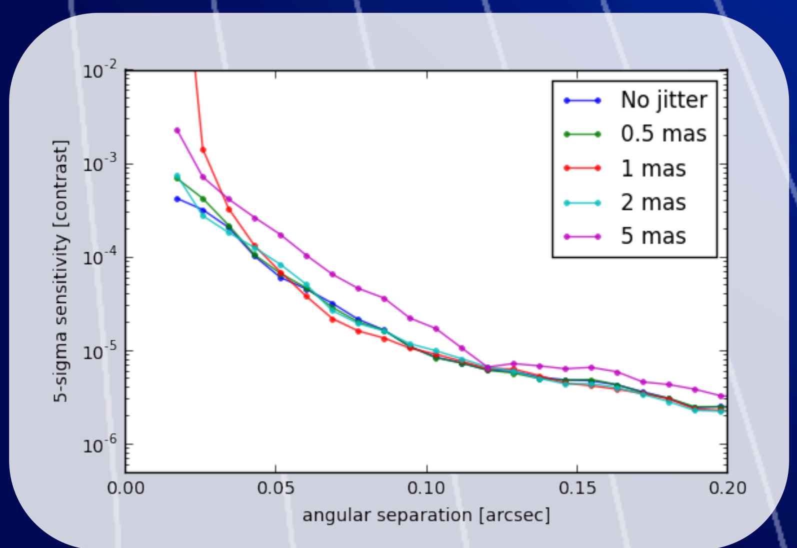


Fig. 11. Contrast performance for the high frequency jitter.

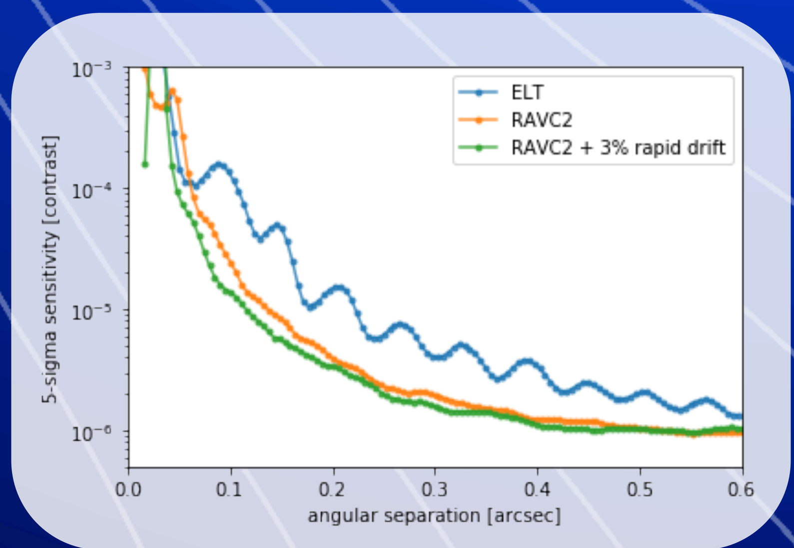


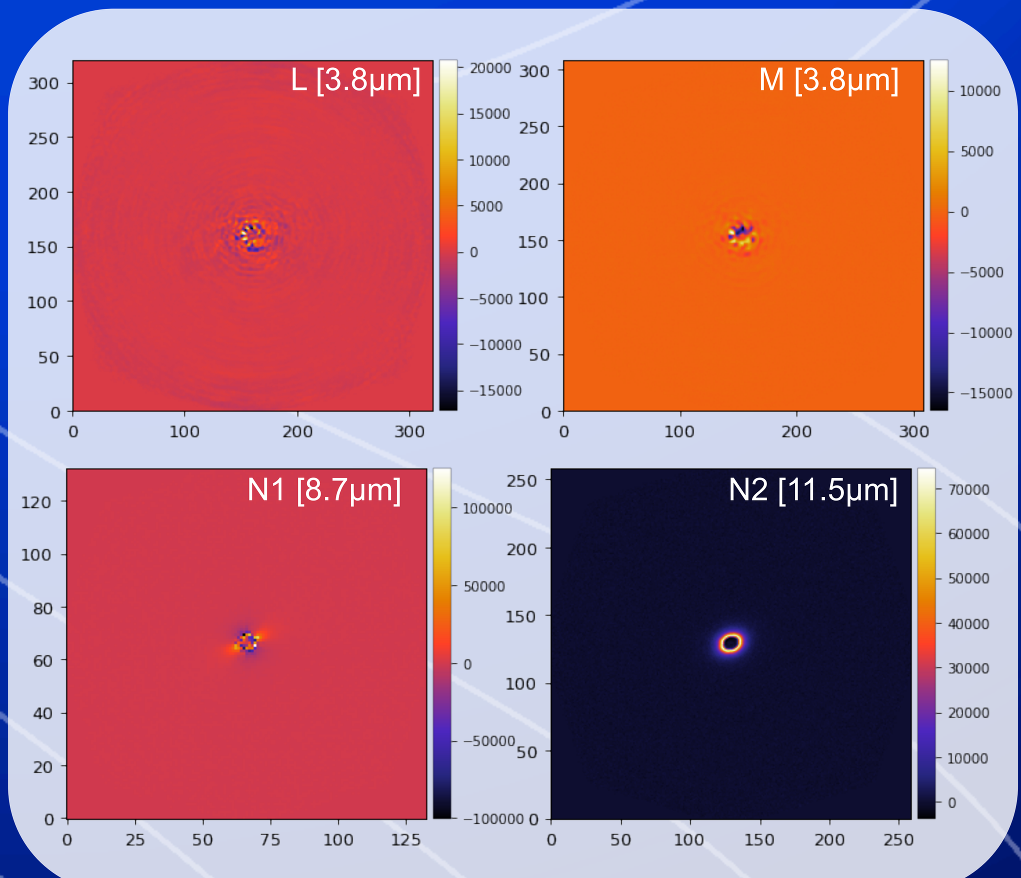
Fig. 12. Contrast performance for the dynamic alignment errors.

IV. Scientific Capabilities: Disk

An important science case for the METIS instrument is the formation and evolution of disks. We present two sets of simulations (Eta Crv and Sun-type star) in a first attempt to define the instrument capabilities, with the RAVC.

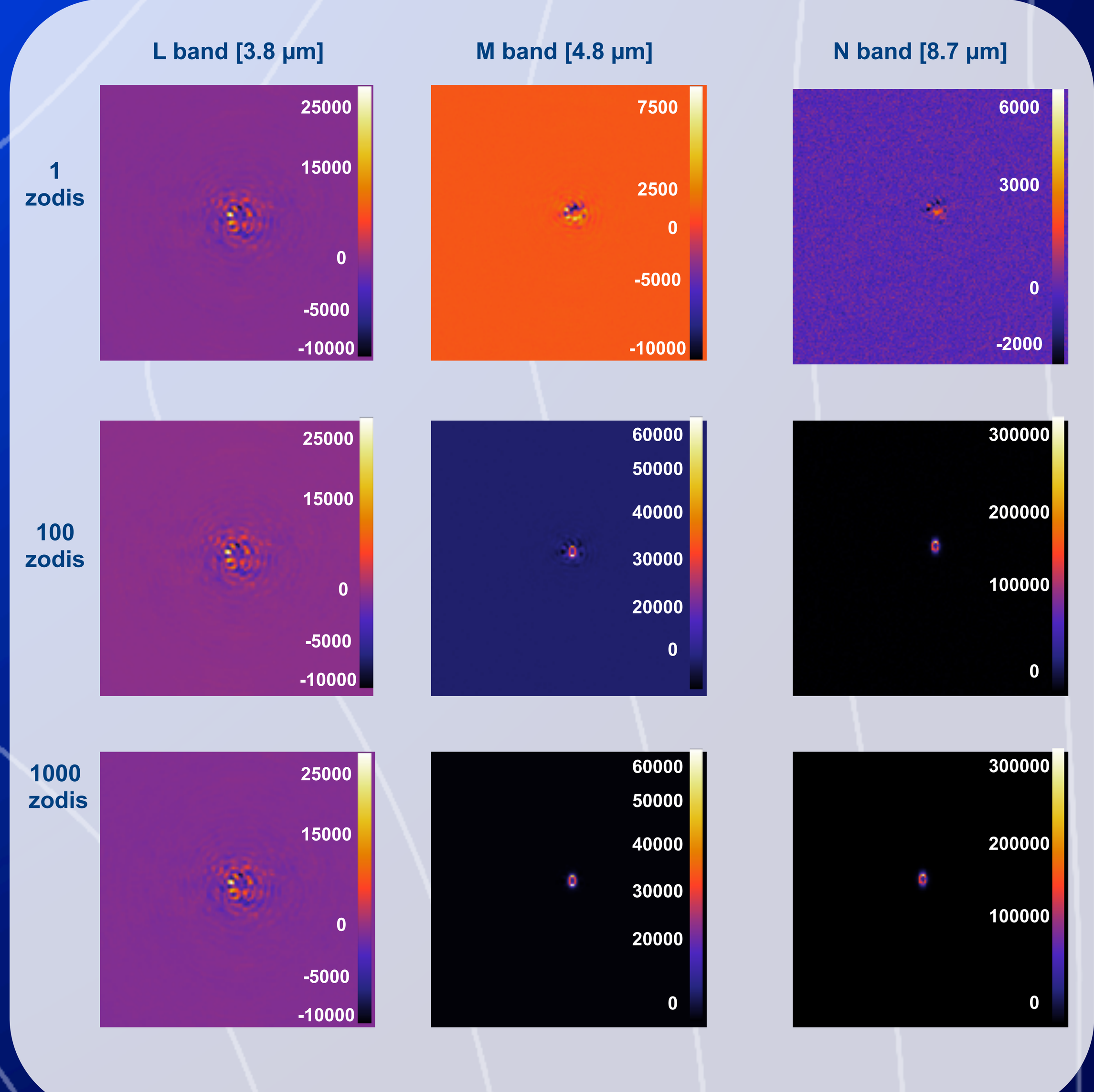
Eta Crv

The Eta Crv[7] disk is very peculiar, because of its strong infrared excess emission despite an age of ~1.4Gyr. The debris disk presents two distinct dust populations: a cold belt at ~180 AU and an inclined disk at ~150 AU. A warmer inner disk at ~3.5 AU should be responsible for the mid- infrared excess radiation.



Sun-type star

This second science case is modeled with the help of the *ZODIPIC* IDL package. It is a Sun-type star, at 10 parsec, with various levels of zodis: from 1 zodis (our solar system) to a much higher level (1000 zodis). The simulations have been performed at 3 different bands: L [3.8 μm], M [4.8μm] and N [8.7 μm]



1. Brandl et al, 2008: METIS- the Mid-infrared E-ELT Imager and Spectrograph
2. Kenworthy et al, 2007: First On-Sky High-Contrast Imaging with an Apodizing Phase Plate
3. Mawet et al, 2005: Annular Groove Phase Mask
4. Mawet et al, 2013: Ring-Apodized Vortex Coronagraphs for Obscured Telescopes. I. Transmissive Ring Apodizers
5. Feldt et al, 2016: Sensing wavefronts on resolved sources with pyramids on ELTs,
6. Gomez Gonalez et al, 2017: VIP: Vortex Image Processing pipeline for high-contrast direct imaging of exoplanets
7. Lebreton et al, 2015: Models of the Eta Corvi Debris Disk from the Keck Interferometer, Spitzer and Herschel